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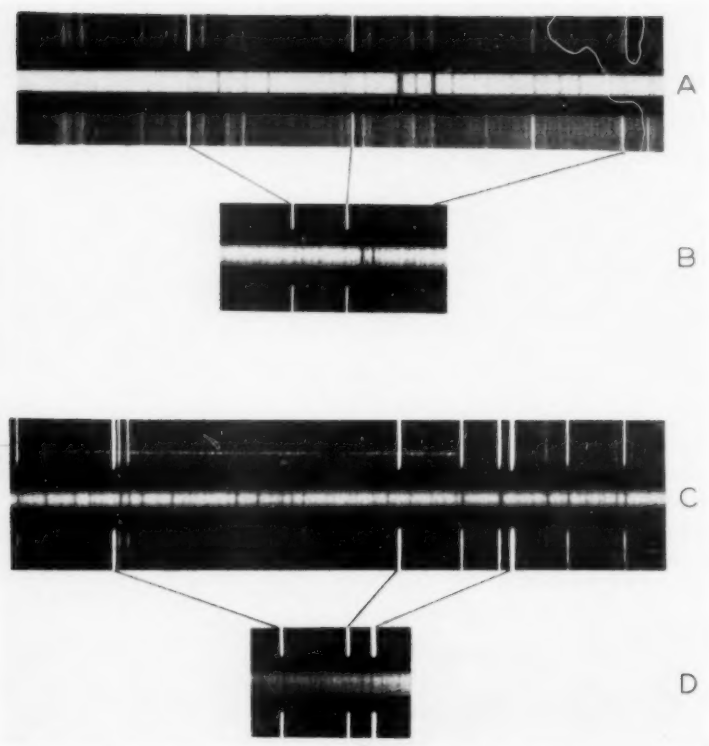
PLATE XXV



Comparison of old and new forms of spectrogram in the yellow and red.

A—The spectrum of α Bootis in the region of the Sodium D-lines, second order of the grating Littrow form.

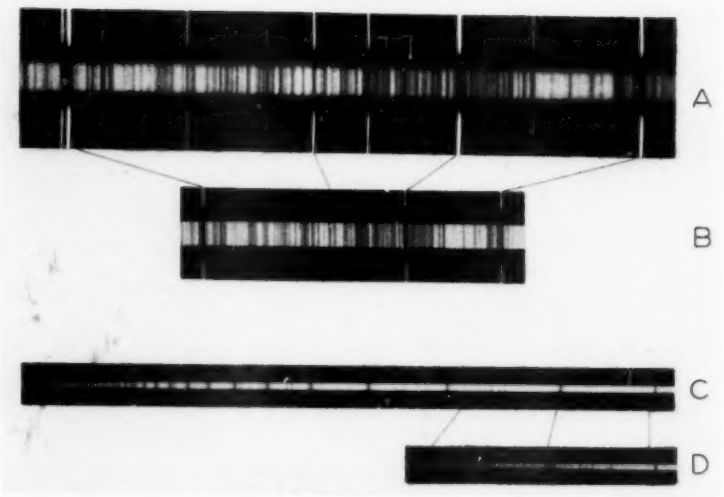
B—The same as A with three prisms and long cameras.

C—The spectrum of α Ursae Majoris in the region λ6310— λ6430, second order of the grating, Littrow form.

D—The same as C with three prisms and long camera.

All spectrograms in this plate are reproduced with magnification 6 times.

PLATE XXIV



Comparison of old and new forms of spectrogram in the violet region.

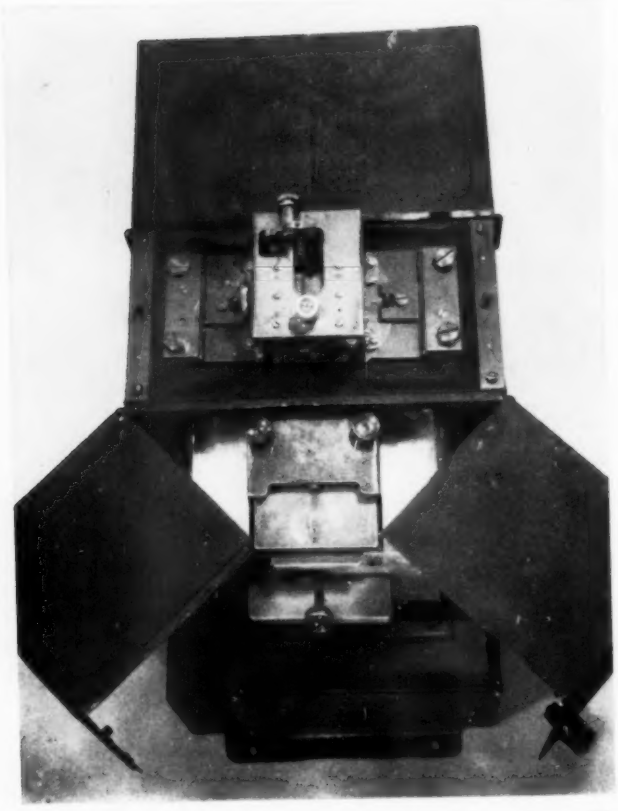
A—Solar spectrum $\lambda 4270 - \lambda 4325$ region with Littrow form of spectrograph, six-prism dispersion.

B—Solar spectrum, the same region as A, taken with three prisms and long (96 cm.) camera, and enlarged to the same extent as A (namely 6x)

C—Spectrum of α Cygni from $\lambda 3940$ down to $\lambda 3640$, obtained with the third order of the grating in Littrow form.

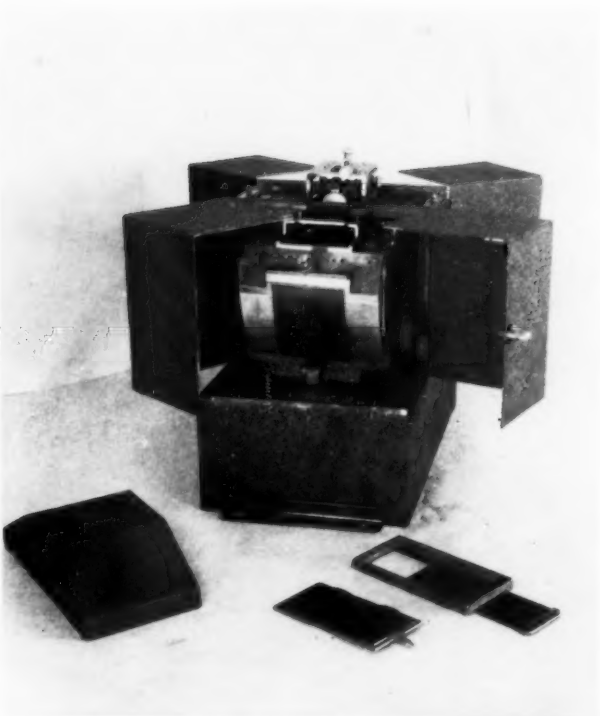
D—The same spectrum as C with three prisms and long camera, $\lambda 3940$ to $\lambda 3830$. (Magnification of C and D is 1.5 times originals.)

PLATE XXIII

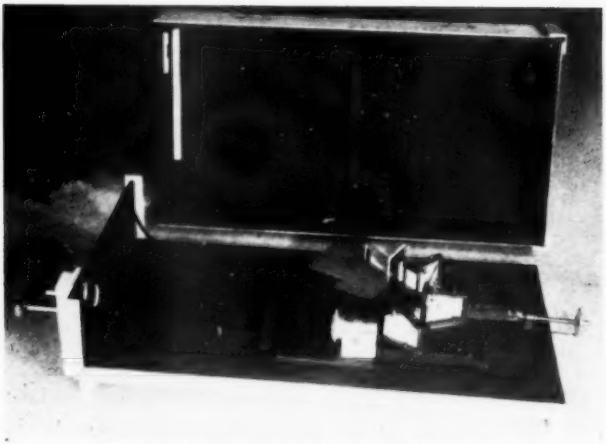


The complete slit head and camera assembly viewed from above. The doors at one end of the sheet metal casing are open. The light tight leather bellows connecting camera and casing are shown.

PLATE XXII



End view of the complete slit-head and camera assembly. In the foreground is a plate-holder and the protecting cover for the slit-head mechanism.



a. The wooden experimental Littrow Spectrograph.

b. Camera of the Littrow Spectrograph without the slit-head assembly attached. The two plate-holders for 2 inch by 4 inch plates are in place.

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VOL. XL, NO. 10 DECEMBER, 1946 WHOLE NO. 359

A NEW LITTROW ARRANGEMENT OF THE VICTORIA STELLAR SPECTROGRAPH*

By C. S. BEALS, R. M. PETRIE AND A. MCKELLAR

(With Plates XXI-XXV)

ABSTRACT

A description is given of a new Littrow arrangement of the Victoria stellar spectrograph which makes possible large increases in dispersion without interfering with the use of the original one-, two-, and three-prism forms of the instrument. This result is achieved by causing the collimator (of 114 cm. focal length) to act also as the camera lens in an auto-collimating system by means of which the spectrum is recorded on two four-inch plates mounted end to end on either side of the slit. The dispersing system may consist of a grating mounted directly behind the collimator-camera lens or, alternatively, of one, two or three prisms with a mirror to reflect the dispersed beam back on itself. When the prisms are used in this way the dispersion is doubled and becomes equivalent to that of two, four or six prisms.

Since both the collimator and the prisms occupy the same position as in the more conventional form of the instrument the only major alteration necessary was the replacement of the cantilever member holding the slit assembly by another of sufficient size to transmit the returning beam and of stiffness adequate to support the combined camera and slit-head made necessary by the new arrangement. Details of the design are given and it is demonstrated that flexure effects are reduced by the new construction. The figuring of an optical flat for use as a mirror with the prismatic arrangements is described.

A table of dispersions indicates the flexibility of the instrument with maximum values of 4.5 A./mm. for 3rd order grating and 2.0 A./mm. for six prisms, while specimen spectra show excellent definition and satisfactorily high resolving power. Exposure times have in general proved to be less than expected and it is anticipated that added efficiency will result from the fluoriding of optical surfaces.

*Contributions from the Dominion Astrophysical Observatory No. 5.

THE original spectrographic equipment of this Observatory, which included a universal spectrograph, making use of one, two or three prisms, was of high quality and considerable flexibility, giving dispersions ranging from 90 to 4.5 A./mm., depending on the region investigated. However, various recent developments in astrophysical research have indicated the need for still higher dispersion, especially in the long wave-length region of the spectrum. Some of these developments include the necessity for the resolution of individual band lines in late type spectra; the study of the profiles of complex interstellar lines; the detection of very faint interstellar lines due to both atoms and molecules; the study of equivalent widths in solar type spectra where many of the faint and closely grouped lines are difficult to resolve; and the study of stellar line profiles in stars like P Cygni, α Cygni or other narrow lined objects of unusual interest.

A number of other institutions, including the Mount Wilson, McDonald, and Radcliffe Observatories, have met the requirements of such investigations by the use of stationary spectrographs fed from the telescope by means of extra reflections, making use of the well known Coudé principle. The advantage of such stationary spectrographs is that they are not subject to flexure and so do not have the same limitations as to size and focal length as a spectrograph directly attached to a telescope.

Unfortunately the use of a Coudé arrangement at Victoria would involve the rebuilding of the telescope mounting, as well as other expensive and inconvenient changes in the dome building, so it was decided to embark on a series of experiments aimed at achieving a comparable result by less radical methods.

A first step was taken several years ago when a grating-prism combination was incorporated into the optical system of the Victoria universal spectrograph and used for observations in the visual region. This arrangement, which has been previously described[1], proved very useful and was successfully employed to resolve the components of complex interstellar sodium lines, to study the visual spectrum of α Cygni and for a number of other investigations requiring high dispersion in the visible region. The grating-prism combination, however, suffered from certain definite defects which limited its usefulness in the following ways: (1) the dispersion curve was of

[1] *J.R.A.S.C.*, vol. 32, p. 369, 1938.

peculiar form and was not easily represented by a simple mathematical formula, (2) the absorption of the glass prism limited the region which could be investigated and made it impossible to take advantage of the high ultraviolet reflectivity of aluminum-on-glass gratings, (3) the combination of prism and grating gave less perfect definition than that obtained from the same optical parts used separately, (4) the spectrum was limited to a single plate, four inches long, allowing only a small proportion of the usable region to be photographed at one time. It was accordingly decided to study the possibility of further improvement by incorporating a Littrow arrangement into the spectrograph, making use of the present collimator lens and employing either prisms or gratings at will as the dispersive elements.

The Experimental Spectrograph

In planning the Littrow spectrograph it was proposed to make use of the following optical parts already in the possession of the observatory: a collimator lens of 6.3 cm. aperture and 114 cm. focal length; three 63° prisms of height 6.3 cm. and base 13.5 cm.; and two aluminum-on-glass gratings, 14,500 lines to the inch, ruled by R. W. Wood, one of which concentrated most of the light in a single first order while the other had a strong second order covering the region λ5000-λ6700. It would have been advantageous to have a somewhat larger lens and larger prisms but since the construction of the spectrograph did not readily permit the installation of larger optical parts it was necessary to make use of those on hand.

In order to test the optical performance of the various possible combinations an experimental spectrograph was set up in the observatory workshop and its construction is illustrated in Plate XXI*a*. The collimator lens and dispersing elements were mounted together on a platform which could be moved toward, or away from, the slit by a micrometer screw. A slit was borrowed from a laboratory spectrograph and a plate-holder was set up near the slit. When prisms were used, a spare prism with its face silvered served as a mirror to reflect the light back along its path. In order to make use of the gratings the prisms were removed and the gratings set up immediately behind the lens.

Referring to Plate XXI*a*, in the first trials the plate-holder was set up close to and above the slit. Examination of the spectra secured in this way indicated that the lines were inclined at a considerable

angle to the slit. This had been anticipated since inclined lines are characteristic of this particular optical arrangement but it was desired to test the magnitude of the effect*. Since it was immediately apparent that the instrument in that form could not give the desired performance, subsequent experiments were made with the plate-holder mounted on a level with the slit and somewhat to one side as shown in the illustration. This resulted in a virtually undistorted spectrum although, owing to the necessary distance of the plate-holder from the slit, a certain amount of vignetting was introduced.

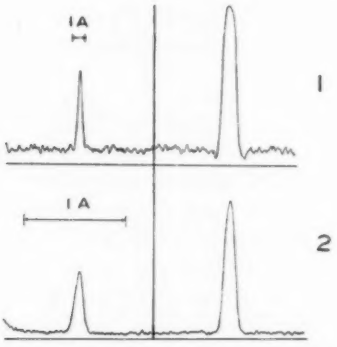

Fig. 1.—Microphotometer tracings of neon and iron comparison lines photographed with the experimental spectrograph.

(1) Neon comparison lines, grating, first order. λλ 6128.45, 6163.59.

(2) Iron comparison lines, six prisms, λλ 4132.90, 4134.68.

This did not interfere seriously with the optical tests but subsequent work on the design was concentrated on getting the end of the photographic plate as close as possible to the beam of light passing through the slit.

In carrying out the tests three different optical arrangements were set up; first order grating, second order grating, and three prisms used with a mirror, an arrangement which gave, effectively,

*In many laboratory spectrographs of Littrow form the plate is effectively above or below the slit but the long focal length and the use of a totally reflecting prism make the effect on the spectrum inappreciable.

six-prism dispersion. A neon discharge tube was used in testing the performance of the gratings. Both first and second orders were investigated and the quality of the spectral lines was highly satisfactory. In fact, the writers have seldom seen more beautifully defined spectral lines, an eloquent testimonial to the performance of the Brashear collimator lens and the Wood gratings.

The six prisms were tested with an iron arc as a source in the region from λ4800 to λ4000. We were prepared to accept a somewhat lower standard of line quality for this arrangement and indeed the lines were not quite as sharp and fine as those obtained with the grating. Nevertheless, the difference was small and the line quality very good, especially when the large dispersion of the six prisms (about 3 A./mm.) is considered. A comparison is made in figure 1 where microphotometer records of lines obtained with the grating first order and the six prisms are shown. When it is recalled that in the case of the six prisms the beam of light must, effectively, pass through twelve separate optical surfaces and be reflected from a thirteenth in addition to passing twice through the lens, then the performance of the spectrograph must be regarded as highly satisfactory.

On the basis of these tests of optical performance it was decided to proceed with the project of the construction of a Littrow stellar spectrograph as an adjunct to the present instrument.

General Design

The Victoria stellar spectrograph, which has been described in detail by J. S. Plaskett[2], consists of a large aluminium casting supported at three points, with a cantilever member projecting from it to hold the slit head. This cantilever was an aluminium casting of rectangular cross-section with walls $\frac{3}{8}$ inch thick, tapering from 7 inches in width at the bottom to $4\frac{1}{2}$ inches at the upper end. The length of the casting itself was $17\frac{5}{8}$ inches while the slit mechanism, which was carried on a steel tube, projected 6 inches above the top of the casting. The cantilever had a cylindrical projection on its lower end suitably threaded so that it could be screwed directly into the main casting of the spectrograph.

The general problem of design was to replace this cantilever with another member of rigidity adequate to support a combined camera and slit-head mechanism at the upper end, the new member being

[2]*P. Dom. Ap. O.*, vol. 1, p. 81, 1922.

required to allow sufficient room for the returning light beam and not to interfere in any way with the operation of the original one-, two- and three-prism forms of the spectrograph. The manner in which this problem has been solved is illustrated in figure 2. This diagram shows the spectrograph with the new cantilever member attached, the combined camera and slit head also being in position. The three prisms and mirror are arranged for six-prism dispersion while the position of the grating is illustrated by dotted lines. It will be seen that the new cantilever member is bolted to the main casting and the camera slit-head mechanism is also attached to the

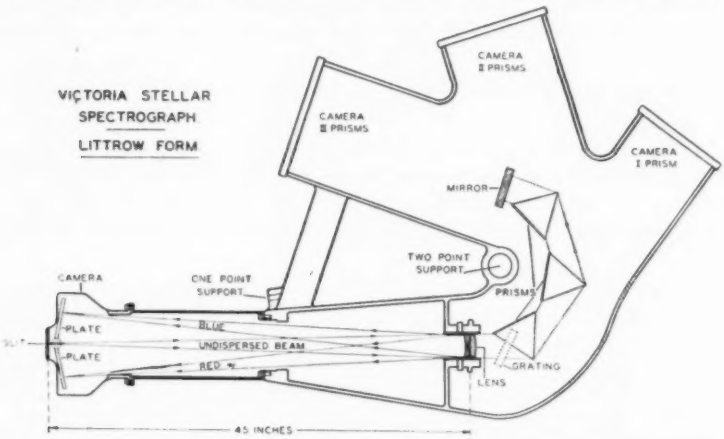

Fig. 2.—Diagrammatic representation of the Victoria Stellar Spectrograph showing the new Littrow arrangement.

upper end by bolts. The position of the plate-holder, somewhat closer to the lens than the slit, is shown although the mechanism for opening and closing the slit and admitting light from the comparison arc has been omitted. More detailed descriptions of the various parts follow.

Form of Main Cantilever

For the cantilever it was at first proposed to make use of an aluminium casting but at the time the work was begun (early in 1941) aluminium was scarce and urgently needed for war purposes. As a consequence it was decided to make use of a steel member of square cross section welded from $\frac{1}{8}$ inch plates with end flanges of $\frac{3}{8}$ inch

material. Additional stiffness was secured by the use of steel ribs, inside and out, welded to the walls. The complete structure was 14 inches long from flange face to flange face with outside dimensions 7 inches square. At the upper end where the light beam passed through to the camera the width was increased to $7\frac{1}{2}$ inches by means of inserts welded into position. The lower flange was internal while the upper flange was external in order to allow for the increased width of the beam. Twelve bolts were used to attach the steel member to the rest of the spectrograph while the camera was attached to the upper flange with eight bolts. It was found necessary to enlarge somewhat the hole in the original spectrograph casting in order to prevent vignetting of the returning beam.

The Combined Slit Head and Camera

The design of this part of the instrument is illustrated in Plates XXI*b*, XXII, and XXIII. Plate XXI*b* shows the camera without the slit assembly. Two plate-holders for 2×4 inch plates are mounted end to end and the light beam from the slit passes between them. In an ideal arrangement the slit and the sensitive emulsion would be in the same plane but this could not be accomplished without a considerable increase in the distance between the plates, with a resulting loss in spectrum. The plate-holders accordingly were mounted one inch closer to the lens than the slit, as shown. Optically this involves a minute departure from the parallelism of the beam as it passes through the dispersive system but it is not to be expected that it would have an observable effect on the purity of the spectrum. The two plate-holders are mounted on sectors which have a common pivot one inch from the plane of the slit and the pivot is so placed that it is centrally cut by the plane of the photographic plate. Each sector can revolve about the common pivot for the purpose of angular adjustment and the scale for making the settings may be seen in Plate XXII. Once set the sectors are held rigidly in position by four heavy clamps, two of which may be seen outside the camera in Plate XXI*b*. Arrangements are provided for moving the plate-holders at right angles to the dispersion, and precise settings are made possible with the aid of a suitable scale and clamping device. Since each sector is of necessity split throughout most of its length in order to admit the light beam, a flexible blind of light-tight fabric is necessary in order to close the opening which would otherwise admit light to the camera at certain angular settings.

This blind and the space for its roller may be seen in Plates XXI*b* and XXII.

The slit assembly is the same as that used on the original spectrograph as described by Plaskett. Its relation to the rest of the assembly may be seen in Plates XXII and XXIII. It is mounted on a circular plate equipped with a vernier graduated in degrees for accurate adjustment and held in position by two clamps operated by screws.

The camera is enclosed in a sheet metal casing which is illustrated in Plates XXII and XXIII. The casing is bolted to the spectrograph support while a leather bellows, shown in Plate XXIII, provides the necessary flexible connection between the camera and the casing.

Plate-holders

In keeping with the general compactness of the design, four new plate-holders of as small dimensions as possible were constructed and one of them may be seen in Plate XXII. In order to save space the back of the plate-holder was made without a hinge and is held securely in place by a small milled catch working internally as shown in Plate XXII.

Focussing

Arrangements for adjusting the inclination of the plates are included in the camera design but the remainder of the focussing is done by moving the lens. This is accomplished with the aid of a brass ring $3\frac{3}{4}$ inches in diameter and $1\frac{3}{4}$ inches long, having internal threads of $\frac{1}{4}$ inch pitch. This ring is constrained to move in rotation alone, longitudinal motion being prevented by suitable guides. The threads in the brass ring engage with external threads on a sleeve attached to the steel tube holding the collimator-camera lens. This tube is free to move longitudinally but rotation is prevented by four symmetrically placed guides interposed between breaks in the threads. A rotational motion of the brass ring thus applies a smooth movement of translation to the lens. Since the force is applied symmetrically the motion is more uniform than in rack and pinion focussing. Lugs are provided for the rotation of the ring and linear settings are read on a vernier. A clamp is provided to fix the lens in position when the instrument is in focus.

Grating Holder

The grating holder is mounted on a base of $\frac{3}{8}$ inch steel designed to fit in the position ordinarily occupied by the first prism. Rota-

tional adjustment is provided by a worm and worm-wheel $4\frac{3}{4}$ inches in diameter while a vernier graduated in degrees and reading to tenths makes it possible to return accurately to the same wave-length region. The steel base of the assembly is provided with a three-point support, with push-pull screws so oriented for lateral motion that the spectrum can easily be centred on the plate.

The Optical Flat

The prismatic spectrograph in the Littrow form requires the use of a reflecting half-prism or optical flat to return the beam through the prisms and collimator-camera lens. Since the Observatory did not possess a half-prism it was decided to employ a flat. In 1942 conditions made it virtually impossible to purchase optical equipment of this sort and it was decided to make the flat at the Observatory.

The production of a surface optically flat has been described in detail in many books and monographs[3]. The method selected here was to begin with three blanks, fine grind them together in a definite sequence, and after preliminary polishing, to polish and figure the most promising one. Emery flour and kerosene were used for the fine grinding which was performed in spells of 3, 2 and 1, minutes for each pair of blanks. Then each blank was given 24 minutes polishing prior to preliminary testing. All the polishing and figuring were done in a pitch-beeswax lap with a rouge-water mixture and all the work was done by hand.

Testing was done by observing the interference fringes formed by the surface being tested and one face of an objective prism, known to be flat. The source of light producing the fringes was a mercury arc used with a green filter. The details of polishing and figuring need not be elaborated here. We were not free from the tribulations which try the spirit and tax the ingenuity of the somewhat inexpert hand worker producing an optical surface. It may be of interest to note that we found paper patterns pressed into the lap (cold) to be very satisfactory for producing temporary changes in its polishing surface. Also, the oft-quoted advice to make exten-

[3] See, for example, *Amateur Telescope Making,* Scientific American Publ. Co., 1935, p. 57 and p. 241, *Amateur Telescope Making, Advanced,* Munn and Co., 1937, p. 113, and *Procedures in Experimental Physics* by John Strong, Prentice-Hall Inc., 1938, Chap. II.

sive use of cold-pressing before polishing was found to be very much worthwhile.

Since the mirror was to be used at practically normal incidence a certain departure from perfect flatness could be tolerated. A surface everywhere flat within one-quarter of a wave was considered acceptable and we were gratified to find that this was well within our resources. The mirror as finally accepted was quite flat save for one section of about $\frac{1}{4}$ of its area where the maximum departure was estimated to be about one-fifth of a wave (1/250,000 inch). A sketch of the fringes as given by the final figure (from visual inspec-

Fig. 3.—Sketch of the fringes showing the form of the flat acceped.

tion) shown in figure 3 indicates the deviation from perfect flatness The surface falls short of a perfect polish but in performance the flat has quite come up to our expectations. The accompanying reproduction of the solar spectrum using the six-prism form, Plate XXIV, demonstrates the excellent definition with the flat in the optical train.

Installation

No serious difficulties were encountered in installation. Owing to the size of the camera it was necessary first to install the main casting of the spectrograph in its three-point support and then to introduce the camera and its supporting cantilever from above. This necessitated the removal of the entire spectrograph assembly from the telescope, a task which took the better part of a day's work. The camera interfered with the operation of the iron comparison arc which was formerly mounted on the spectrograph support south of the slit. It was found necessary to remount the arc west of the slit and install a stainless steel mirror on the slit

assembly in order to reflect the light into the spectrograph. The guiding telescope also had to be remounted since its original mounting was integral with that of the arc. In this case, however, the original position south of the slit was not altered. These changes made it possible to eliminate certain awkward aspects of the original arrangement and the final result represented a distinct improvement in convenience and accessibility.

TABLE I

DISPERSIONS AVAILABLE WITH LITTROW SPECTROGRAPH
(in Angstrom units per mm.)

Wave-length	3933	4350	5890	6563
2 Prism	5.7	9.0	32.4	42.9
4 Prism	2.9	4.5	16.2	21.5
6 Prism	2.0	3.0	10.8	14.3
Grating, 1st Order	15.0	14.8	14.6	14.5
Grating, 2nd Order	7.3	7.2	7.0	6.8
Grating, 3rd Order	4.7	4.5	4.3	4.2
Three-prism Spectrograph*	4.5	7.1	22.0	34.0

*Dispersions available with original spectrographs, included for comparison.

COMPARATIVE USEFULNESS OF VARIOUS ARRANGEMENTS

In Table I are listed the various dispersions available with the Littrow Spectrograph. Not all have been tried in practice since some fulfil more definite needs than others. The advantage of grating, over prismatic, dispersion in the visible region is very great and it will be seen from the table that the second order of the grating provides nearly five times the dispersion of three prisms at Hα. In the region below λ4300 the advantage lies with the six-prism arrangement insofar as dispersion alone is concerned but the increasing absorption of the prisms limits its usefulness in the regions of shorter wave-lengths.

Further remarks on the comparative performance of gratings and prisms follow.

a. *Gratings.* When the Littrow spectrograph was originally designed it was assumed that the prismatic arrangements would always be faster than the gratings for comparable dispersion but this has not turned out to be the case. The second and third orders of one of our gratings have proved to be considerably faster than the six prisms. The grating in question was ruled by Wood to con-

centrate a large proportion of the light into the second order of the region λ5000–λ6700. The same grating is correspondingly fast in the third order in the region λ3300–λ4500. Since the collimator lens is relatively transparent well into the ultraviolet it has been found possible to make use of the third order of the grating to investigate the short wave-length region as far to the violet as λ3500 thus opening to us a region previously inaccessible except with dispersion of the order of 70 A./mm., see Plate (XXIV)C. It is thus possible to study the spectrum of a star from λ3500 to about λ4500 with a dispersion of 4.5 A./mm. and from λ5000 to λ6700 with a dispersion of 7 A./mm., making possible investigations which could not have been undertaken here before this equipment became available. Stars as faint as the fifth magnitude have been successfully studied with the above dispersion and the gratings have practically superseded the old three-prism arrangement, both in the ordinary and visible regions of the spectrum.

In addition to the grating already mentioned, a second grating is available which concentrates most of the light in the first order. The entire spectrum from λ3850 to λ6700 is covered on two four-inch plates with a dispersion of 15 A./mm. The uniform dispersion given by this arrangement is especially good for the accurate comparison of the intensities of lines occuring in widely separated regions of the spectrum and it is expected that increasing use will be made of it for this purpose in the future.

b. *Prismatic Dispersions.* The possibilities of the prismatic dispersions have not yet fully been explored, mainly because the gratings have so far fulfilled most of the Observatory's requirements for high-dispersion spectra. However, in the region λ4000–λ3900 the six prisms give approximately twice the dispersion of the third-order grating. This arrangement is thus of great value for the investigation of the profiles of narrow lines in the brighter stars and it is proposed to use it mainly for this purpose. The four-prism arrangement has not yet been used for actual stellar observations but, as may be seen from the table, its dispersion is superior to that of the third order of the grating in the region of λ4000. It is expected that the speed will be considerably greater than that of the six prisms and it may well prove to be the more useful combination of the two. It is proposed, as soon as possible, to have the prisms coated with non-reflecting fluoride compounds, and it is expected that this will result in a considerable improvement in efficiency.

The performance of the new form of the spectrograph and its capabilities as compared with the older form are illustrated in Plates XXIV and XXV. A and B, Plate XXIV, reproduced with the same magnification, show the great gain with 6 prisms over the best dispersion and resolving power available previously. In C the remarkable extension of the third order grating spectrum into the near ultraviolet is well shown. The three-prism spectrogram, D, while slightly superior in resolution, absorbs so strongly below λ3830 that studies in the ultraviolet with this instrument were entirely impracticable. The improvement in dispersion and resolving power, in the visual region, given by the grating over the 3-prism arrangement is quite evident in Plate XXV.

The Differential Flexure

As may be seen from figure 2 the Littrow arrangement in no way interferes with the use of the spectrograph in its original one-, two- or three-prism forms. Accordingly our first test was to determine whether the new cantilever member, with camera attached, had introduced additional flexure when used with the single-prism arrangement. To do this the medium focal-length camera was installed and spectra of the iron arc were photographed side by side on the same plate, first with the telescope in the zenith and secondly with it directed to the south point of the horizon. These spectra showed a relative displacement of 0.003 mm. (6 km./sec.) which corresponds to a movement of the slit equal to 0.005 mm. if the total deflection be assumed to be due to bending of the cantilever. The same test made with the original cantilever indicated a greater displacement of the slit, i.e., 0.008 mm. according to J. S. Plaskett.[4] We conclude from this that the stiffness of the new member is greater than that of the original and that the additional load due to the camera at the slit end has not adversely affected the performance of the spectrograph.

In order further to compare the new and the old structures the deflections at the slit end were calculated from the usual formulae[5]. The new cantilever is 14 inches long, the cross section is square and 7 inches on a side, with external and internal ribs as previously described, and its total weight is 30 lb. The combined camera and

[4] *P. Dom. Ap. O.*, vol. 1, p. 95, 1919.

[5] See for example Morely, "Strength of Materials", (Longmans, Green and Co.) chaps. 5 and 6.

slit projects 8 inches beyond the end of the cantilever and weighs 16 lb. The deflection of the slit, due to the bending of cantilever and slit assembly, when the telescope is horizontal is calculated to be a little less than .001 mm. and a similar calculation, for the original cantilever and slit-tube assembly, indicates a flexure about four times as great. This strengthens the conclusion that the modified spectrograph is stiffer than the original structure, and if further confirmation were desired it is provided by high-dispersion spectra made with long exposures. The flexure perpendicular to the dispersion is now less than formerly even with exposures lasting several hours.

Actually it is doubtful if more than a small fraction of the flexure is contributed by the cantilever member, as the above calculations show. The rest of the spectrograph weighs several hundred pounds and, although well braced, is no doubt the cause of the major portion of the differential flexure. After three years of experience we have every reason to be satisfied with the performance which has fulfilled expectations based upon calculations outlined above. For any reasonable hour angle the differential flexure is satisfactorily small, the grating arrangement especially indicating much smaller flexure effects than the older three-prism arrangement.

In conclusion we wish to record our indebtedness to Mr. S.S. Girling who carried out the alterations to the spectrograph in his Victoria machine shop two years before joining our staff and assuming charge of the Observatory Machine Shop. Mr. Girling was able to arrive at a particularly happy solution of the problems posed by the camera slit-head combination. This part of the instrument was almost entirely his design and, both from the point of view of convenience of operation and appearance, is a beautiful example of the instrument maker's art.

Dominion Astrophysical Observatory
Victoria, B.C.
July 1946

MONTREAL CENTRE SECOND ANNUAL STAR NIGHT

By Isabel K. Williamson

ENCOURAGED by the success of our first public "Star Night", the Montreal Centre made plans this year on a more elaborate scale. The City of Westmount, when approached for permission to hold the event in Westmount Park, gave the project its enthusiastic support, arranging for the screening of street lights, the installation of a public address system, and helping in numerous other ways.

DeLisle Garneau, Director of Observations, and his Committee were delighted also with the co-operation they received in other quarters. For a week prior to the event the Westmount Library and the Mechanics Institute featured astronomical books, and Burton's Limited and the Montreal Book Room arranged window displays around small telescopes lent by the Society. Waterman's Fountain Pen offered the use of its display window on St. James Street, and here the Centre's 12-inch reflector was on show, surrounded by an orrery, a celestial sphere, an armillary sphere, and books from the Centre's own library. Publicity also included a fifteen-minute radio talk over Station CFCF by Henry F. Hall, President of the Montreal Centre.

In anticipation of a goodly crowd, the Committee mustered as many telescopes as possible—nine refractors and eight reflectors. The latter, with the exception of the Centre's 12-inch, were made by members of the Society, several having been completed since the first Star Night of a year ago.

With all our plans completed, our chief worry, as usual, was the weather. Star Night was scheduled for nine o'clock on the evening of Tuesday, 4th June, with the understanding that it would be postponed until Wednesday or Thursday if necessary. Tuesday was unsettled, with thunderstorms predicted. As the decision had to be made early in the afternoon, we finally decided to go ahead, but we had many uneasy moments between three and nine o'clock. At 8.45, with the sky completely overcast, we were about to admit that we'd have to call it off—when Venus broke through the clouds, then the Moon, then Jupiter. Telescopes were hurriedly set up in position and the programme was soon in full swing.

Star Night was opened officially by R. Percy Adams, Mayor of Westmount, with Daniel P. Gillmor, K.C., immediate Past President of the Montreal Centre, as master of ceremonies. Mr. Garneau then announced the celestial objects to be viewed through each telescope, and the spectators, who by this time numbered several hundred, lined up to wait their turn. A short talk about the Moon by Henry F. Hall was followed by one on Jupiter by E. Russell Paterson. Then, when the sky became dark enough, F. DeKinder pointed out the main constellations. A series of slides, with commentary by John W. Duffie, provided an added attraction.

Programmes handed to each visitor gave information regarding the celestial objects being observed. Venus and Saturn were lost from view earlier than expected because of cloud banks on the western horizon, but Jupiter and the Moon were visible all evening, the dome of the sky remaining remarkably clear from nine until eleven o'clock.

Park officials, experienced at judging crowds, estimated that over fifteen hundred people attended. As one Committee member remarked later, "If we had had a really good night, we wouldn't have been able to handle the crowds. Next year we'll need twice as many telescopes!" That sounds ambitious but it might be possible, for several more reflectors are already in course of construction, and the interest shown by the public has undoubtedly been a stimulus to the Centre.

Montreal, P.Q.

HER MAJESTY'S MAGNETICAL AND METEOROLOGICAL OBSERVATORY, TORONTO

By A. D. THIESSEN

(*Concluded from Vol. XL, page 264*)

PART XII. *Captain Lefroy goes before a Medical Board and is advised to take leave of absence to return to England, 1850.*

On July 11, 1848, Lefroy lost one of his best friends, Augustus Frazer. He died of cholera. Just before his death in Suedia, Syria, Fraser had completed a tour of the Holy Land. He left Lefroy his residuary legatee, who ultimately received between £3000 and £4000 from the estate.[97]

This legacy made it desirable for Lefroy to return to England some time before 1851 for about three or four months. However, by October 1850, Lefroy had appeared before a medical board, that recommended he should return to England on a brief visit for reasons of health. He left Toronto on November 12th, 1850 and returned again on April 2nd, 1851.

He was in England during the time of the Great Exhibition of 1851.[98] Most of his time was spent, however, "moving backwards and forwards a great deal to Kew or Richmond and Woolwich, with an eye to business."[99]

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[97]Lefroy. *Autobiography*, p. 115.

[98]*Ibid.*, p. 120. "At this time the approaching 'World's Fair,' the great exhibition of 1851, was the theme of endless speculations and rumours, and the building itself was nearly completed before I left town. I was extremely anxious to be allowed to see the inside, but Sir William Reid declared that he had been obliged to refuse a royal duke, and that it was impossible! However, the kindly old man added, 'I generally walk through the building on my way home when the office closes, and if you happened to call upon me about five o'clock, why I might take you with me!' Accordingly I casually did call at that hour, and had the great pleasure of seeing the wonderful structure, with a large part of its contents. The lofty transepts, rising clear over two elms (one of which still survives, 1886-89), struck me more than anything else. There never has been, nor ever can be again, an exhibition of such interest. The grandeur, the beauty, the surprise and novelty of it, the pomp of ceremonial, the youth of the Queen and her husband—all were elements in its success which can never meet again."

The building mentioned was the Crystal Palace, destroyed by enemy action in World War II.—*A.D.T.*

[99]*Ibid.*, p. 120.

During Lefroy's absence a young officer in the command of the Royal Artillery at Toronto, Lieutenant (later Major-General) William Goodenough, C.B., was left in charge of the observatory. With a little instruction Goodenough was competent to carry on the routine work of the observatory, particularly as his assistants had been trained by Lefroy.[100]

Lefroy occasionally refers to the contemporary political scene, and his comment is always interesting, as in the following letter.

Toronto, 30 September, 1848.

My dear Colonel,

You will have been grieved and shocked, I know, by the death of poor Augustus Frazer, so unexpected and so sad under all the circumstances. All the consolation we can have is that it might have been under circumstances much *more* painful. He died surrounded by strangers, but they were in spirit kind and Christian friends, and everything that medical skill could effect was done for him. There is something, too, almost enviable in a summons so timed when his heart and affections had been stirred up by meditations over the scenes of our Saviour's history, and, I have no doubt, his natural piety of character quickened and his Christian hopes confirmed by their influence on his susceptible mind. He has given me no common proof of generous affection by bequeathing to me not only all his books, maps, MSS, together with other effects, but also the residue of his personal property, which at Lady Frazer's death will amount to a large sum, I believe over £4,000. He has made me one of his executors, a responsibility which may make it desirable for me to return to England before 1851, but I do not think that it will. However, should it become necessary, I should be glad to feel at liberty to apply to the Commander of the Forces here for three or four months leave for that purpose. (I presume that it would not be necessary to go to the Master General) and beg beforehand to hold your sanction to my taking that step at my own discretion, being always responsible that the duties of the Observatory are properly carried on during my absence. If it so happened that circumstances were to require my presence in England in February or March, it would be rather advantageous than otherwise as regards the Observatory. I hear that poor Lady Frazer bears her affliction with much patience and I know that she has all the consolation that the utmost kindness and affection can impart, from her niece Mrs. Wood.

Younghusband mentions that you were disappointed at the slight improvement perceptible since your last visit to Ireland. I was much struck by the views propounded in a Pamphlet of Mr. Godby's "An Answer to the Question 'What is to be done with the unemployed poor of the United Kingdom?'" As to the causes of this incurable malady of that unhappy country, I know that nothing so cheerless and discouraging as the aspect of the whole of it, nor do I think that human wisdom will find a remedy. It seems to require a total change of the national heart, a thing society has never yet seen. All classes require alike to be renovated, for the gentry have most of the faults of the peasantry without their

[100] *Ibid.*, p. 118.

virtues, and all this to be effected under the monstrous incubus of Popery in its most debased form. If Lord John Russell returns to England with really useful measures matured, his visit will be an era in Irish history. The circumstance of the Prime Minister investigating the case personally, although exceedingly reasonable, seems to me curiously indicative of the tendency of events to move in circles: it is a return, in the abstract, to personal government, that is, towards Absolute Authority: but then I think that nothing short of Absolute Authority ever will govern Ireland to its own benefit, and the sooner it is admitted the better. I would venture to predict an attack on the Irish Church as the first measure. *The Times* seems to be feeling the way in that direction.

Mrs. Lefroy and our two little ones returned from Niagara this day week, after two months absence, greatly benefited by the change of air. The little daughter whose arrival I so unaccountably omitted to mention last June, is the prettiest infant I have ever seen, and has never given us a moment's uneasiness. I trust, too, after this summer, to have no more from our little boy, who is much less delicate than he was. You probably recollect the Queenston Heights well. They are going to throw a suspension bridge across them. I don't know what the span will be, that of the suspension bridge near the Falls is 800 feet, which is 160 less than the Friburg bridge, but the height is greater, being 240 feet. It is so slight that it really scarcely catches the eye at all as a feature in the scene, and if it does not improve the actual beauties of the spot, takes nothing from them. Mrs. Lefroy joins me in the kindest regards to Mrs. Sabine and yourself, and

Believe me, Yours ever faithfully,

J. H. LEFROY

Montreal, 21st October, 1850.

Sir,

Should it be the decision of the Medical Board before which I am to appear this day, that a temporary absence from the duties of the Magnetic Observatory is necessary for me, I am desirous of making such arrangements as may insure the least amount of inconvenience to the Special Service on which I am employed. I should feel that I had securetl this by leaving the Establishment in charge of some competent officer at the regiment. From conversations I have had with Lt. Goodenough, Royal Artillery, I have ascertained that he is extremely desirous of enjoying so favourable an opportunity of scientific instruction and am persuaded that the Observatory may be advantageously left in his hands.

I shall feel extremely obliged by your allowing this officer, if the exigencies of this station permit it, to be attached to the detachment at the Magnetic Observatory, to assume the charge of it during my absence. I have ascertained that there will be no objection on the part of the Captain of his Company.

I have . . . J. H. LEFROY

Colonel Dynelly, C.B.,
Commanding Royal Artillery in Canada.

This is to certify that I have been Capt. Lefroy's (of the Royal Artillery) medical attendant for some years past, during which period I have several times had occasion to prescribe for him.

He is now (I conceive) in a very delicate state of health, losing flesh fast and becoming highly nervous and excitable. His sight also, from close attention to his duties, is much impaired, and from the little benefit he has derived from medical treatment, I strongly advise his taking a trip to Europe.

I might add that his digestive organs have completely lost their tone, and I believe that they will not materially improve so long as he is obliged to follow his present arduous occupations.

(Signed) EDWARD M. HODDER, M.C.,
Member R.C.S., England.

Toronto, October 15, 1850.

Montreal, 21st October, 1850.

Pursuant to General Orders of this day a Medical Board will assemble at the Garrison Surgery to-morrow, Tuesday, at 2 p.m., to examine into, and report upon the state of health of Captain Lefroy, Royal Artillery.

I. FRENCH,
Inspector General of Hospitals.

Montreal, C.E.,
22nd October, 1850.

Proceedings of a Medical Board held by order of the Lieut. General Commanding the Forces, to examine and report upon the state of health of Capt. J. H. Lefroy, Royal Artillery, aged 33 years.

PRESIDENT
Dr. French, Inspector General of Hospitals
MEMBERS
2nd Class Staff Surgeon Telfer
Staff Assistant Surgeon Dr. Barrett

The Board having perused a statement of Capt. Lefroy's case by his professional attendant at Toronto, and minutely enquired into his present state of health, find

That he is nervous, excitable, and dyspeptic, attended with considerable impairment of vision, which in the opinion of the Board, are the results of close application to his duties, and as he has derived little benefit from Medical Treatment,

The Board are further of the opinion that change of climate and relaxation from his arduous occupations are essentially necessary for the re-establishment of his health and do therefore recommend that he may be granted leave of absence to England accordingly.

I. FRENCH, Inspector General of Hospitals,
I. T. TELFER, Staff Surgeon 2nd Class,
W. BARRETT, Staff Assistant Surgeon.

True copy. (Signed) GEO. SANDHAM,
Brigade Major.

Kingston, October 24, 1850.

My dear Colonel,

It will perhaps surprise you to hear that I have appeared before a medical board and am ordered home. Having forgotten to take a copy of the Proceedings

of the Board before leaving Montreal, I am unable to forward it by this mail, but shall enclose, when I get to Toronto, a copy of the medical certificate on which it was founded. I have been more or less out of health for some time: in want of relaxation and a change. Thinking that a temporary absence from the Observatory could not be better employed than by visiting England, I at last made up my mind to ask leave to come home and report myself. Colonel Dynelly thought it necessary, as I put it on grounds of health, to apply for a medical board, which has recommended that change. I am now therefore on my way back to Toronto (which I left this day week) to make the final arrangements, and expect to take my passage in a sailing packet the first or second week of November. I may be in Woolwich by the end of that month or very early in December. I have applied to Colonel Dynelly to attach Lieut. Goodenough to the Observatory during my absence—he is very young, but very intelligent, zealous, and desirous of the opportunity. The Colonel hesitated a good deal and would give me no positive answers but I am pretty confident will allow it, as Younghusband's is a case exactly in point. If so I hope and believe that an absence of three months will not be attended by any serious inconveniences. Goodenough will of course come at once if at all and get some instruction. My present intention is to bring home Ronald's V.F. magnet for examination, leaving only the Bifilar and Brooke's instruments to be worked, and to work the former exclusively with paper, so as to simplify his duties as much as possible. Smythe, through whose hands Goodenough has passed, wrote to me and spoke of him in the highest terms. He is very highly spoken of at Montreal. Colonel Dynelly's hesitation proceeded altogether from a fear of the Adjutant General's disapproval of his detaching an officer without express authority from him. I am myself persuaded, and tried also to persuade him, that Sir H. Ross will be glad to have an intelligent young officer brought forward and prefer it to leaving the Detachment without a head. All the officers at Montreal, from regard to Goodenough, tried to help him. Should Col. Dynelly after all, decline, I shall apply for an additional N.C. officer and leave Sgt. Walker in charge. I am however on several accounts unwilling to do this. He does not possess Sgt. Johnston's firmness and independence and has a wife whom I have some trouble to keep in order. In coming home thus unexpectedly, my chief desire, next to restored health, will be to turn my time to useful account, and I shall be glad if you will consider and let me know at once on arrival in what manner this can best be done. My own wish is to spend a part of each week, say Saturday, Sunday, and Monday with my family who will be residing in London; the rest at Woolwich, Kew or wherever else I may gain useful experience. I should like to return in January.

There will be a mail at Toronto awaiting me. I shall get in barely in time to add a few lines to this before the departure of the outward one, and will add a postscript should there be anything to report or reply to.

Believe me, Yours very truly,

J. H. LEFROY.

Toronto, Oct. 25.

I find here only your letter of Sept. 30 from Paris. My official letters leave me no time to reply to it. All has gone well.—J.H.L.

Magnetic Observatory, Toronto,
October 25th, 1850.

Sir,

I have the honor to inclose a copy of a certificate from my medical attendant in pursuance of which I proceeded to Montreal on the 17th instant for the purpose of obtaining the permission of Colonel Dynelly, C.B., Commanding the Royal Artillery, to leave the Observatory for a short time in charge of the senior N.C. Officer and to return to England to recruit my health. Colonel Dynelly thought it necessary to apply for a medical board, and I have been recommended to take that step by the Board.

It is my intention to leave Toronto the first week of November, or sooner, if the necessary arrangements can be completed. I do not apprehend that any long leave of absence will be required, and trust to proceed for the carrying on of the routine duties of the Observatory with but little detriment from my temporary absence. I thought it my duty to apply officially for the temporary appointment of Lieut. Goodenough, Royal Artillery, a very active and intelligent young officer, to the charge of the Observatory. To this application I have received no reply. I have . . . J. H. LEFROY.

[Letter to Col. Sabine]

W.O., FORM 471

Commissariat Chest Account

Warrant of the Officer commanding in Canada.
To F.W.A.C. Major Esquire Deputy Commissary General to Her Majesty's Forces:

You are hereby authorized and to issue to John Henry Lefroy, Royal Artillery, or to his assign, the sum of

No. 4 THIRTY POUNDS,

£ 30.0.0. being the amount of the regulated allowance of passage money to enable him to proceed to England for the benefit of his health on the recommendation of a medical board; And for the so doing, this, with the acquittance of the said Captain Lefroy or his assign, shall be your sufficient warrant and discharge.

Given under my hand at Montreal
this 24th day of October, 1850.
By His Excellency's Command
George Talbot,
Military Secretary.

WM. ROWAN,
Lieut. General,
Commanding the Forces.

Magnetic Observatory, Toronto,
Nov. 1st, 1850.

Sir,

I have to call your attention to the inclosed communication from the Brigade Major, Royal Artillery, and request that you will be pleased to furnish in writing without delay, the required explanation of the mode of proceeding referred to.

I have the honour to be
J. H. LEFROY, Capt. R.A.

Lieut. Goodenough,
Royal Artillery.

Magnetical Observatory, Toronto,
November 1st, 1850.

Sir,

I have the honor to acknowledge the receipt of your communication dated October 25th, 1850, directing me to report, with the least possible delay, the date on which I intend leaving Toronto, and to state that it is my present intention to leave it on Friday the 8th instant, and to make my passage in the Royal Mail Steamer from Boston on the 13th instant. The absolute necessity of completing certain arrangements at the Observatory before quitting it, and of conveying a competent amount of instruction to Lieut. Goodenough, may possibly oblige a day or two of longer delay. My departure will be duly reported by him. I beg to take this opportunity of enquiring whether Lieut. Goodenough's servant is to be paid and mustered with this detachment, of whether he will continue to be paid with his company.

I have the honor to be, Sir,
Your most obedient Servant,

The Brigade Major,
Royal Artillery, Montreal.

J. H. LEFROY, Capt. R.A.

Magnetical Observatory, Toronto,
1st Nov., 1850.

Sir,

I have the honor to acknowledge the receipt of your communication dated 28th October, 1850, and have called the attention of Lieut. Goodenough to its contents. That officer has addressed to me the accompanying explanation of his conduct which I forward with the hope that it will be found satisfactory.

I have the . . .

The Brigade Major,
Royal Artillery, Montreal, C.E.

J. H. LEFROY . . .

Toronto, C.W., Nov. 12, 1850.

Sir,

I have the honor to report to you the information of the commanding officer that Capt. J. H. Lefroy left this place for England this day.

I have the honor to . . .

Lt. Col. Palmer, R.A.,
Commanding Royal Artillery, Kingston.

GOODENOUGH, Lt. Royal Artillery.

New York, 16 November, 1850.

My dear Colonel,

I have taken my passage in the *Yorkshire*, Liverpool Packet Ship, to sail this day. As the steamer of the 20th will probably gain a few days on us, I leave these few lines for her. I received your letter of October 22 and Younghusband's of October 25, before leaving Toronto, also authority for withdrawing the Contingent money, etc., in time to arrange all that affair. I believe everything was left in a satisfactory state. Goodenough is pretty well acquainted with his duties. We had obtained several traces on Brooke's new instrument and the arrangements appeared to be perfect enough to enable him to continue the work with little danger of failure. I have a copy of Mr. Abbott Lawrence's letter to Lord Palmerston, and other official letters connected with the continuance of the Observatory, and have seen Mr. Bond, and Dr. Silliman, as well as Guyot, Herrick and other active members of the American Academy and American Association on the same subject. Hoping to follow my letter very shortly, believe me,

faithfully yours,

J. H. LEFROY

(*Conclusion of this series*)

OUT OF OLD BOOKS

By Helen Sawyer Hogg

DEARTH OF SUN-SPOTS IN THE SEVENTEENTH CENTURY

At the present time the sun presents a highly spotted appearance, quite in accordance with expectations of the approach toward maximum in the sun-spot cycle. Nowadays we take for granted the appearance of large numbers of spots on the sun's disc within several years of the maximum of the sun-spot cycle. It is worthwhile recalling that not always has the sun behaved in this manner, and that the seventeenth century is remarkable for a dearth of sun-spots.

An excellent summary of the observations of sun-spots in the seventeenth century is given in *Knowledge,* vol. 17, pp. 173-176, August 1, 1894, by Walter Maunder, who developed the famous "butterfly diagram" of sun-spot frequency. We quote the more significant excerpts from the article.

A Prolonged Sun-spot Minimum

The progress of the sun-spot cycle has been on the whole so regular since Schwabe first demonstrated its existence, that we might easily assume it to be a fundamental law of solar change. Maximum has succeeded maximum, and minimum minimum, at an interval in each case so closely approaching eleven years, that we might confidently expect the present great activity to begin to decline within the next year or so, and to reach a minimum about the end of the century, as a year or two ago we were looking for some such development of spots as we are beholding now.

The sequence of maximum and minimum has, in fact, been unfailing during the present century. Within the experience of living observers the appointed time has never come round without the appearance of spots, vast in area, violent in change, and many in number: and one might be forgiven for inferring that as it has been for so long, it must always be, and must always have been. And yet there is the strongest reason to believe that for something like half a century, if not indeed for the full term of "threescore years and ten" allotted as the span of human life, the ordinary solar cycle was once interrupted and one long period of almost unbroken quiescence prevailed.

If we turn back to the earliest volumes of *Philosophical Transactions* of the Royal Society, we find the first notice of a sun-spot occurs in No. 74, dated August 14th, 1671, where it is stated that "at Paris the Excellent Signor Cassini hath

lately detected again Spots in the Sun, of which none have been seen these many years that we know of". So novel, indeed, was the observation felt to be, that Oldenburg, the Secretary of the Royal Society, and editor of the *Transactions,* evidently considered it due to those interested in science to give an account of the last observations of the kind that had been secured in England. These had been made "by our Noble Philosopher Mr. Boyl", in the months of April and May, 1660; that is to say, more than eleven years before.

Cassini's observations reached London in due course and appear in the next number of the *Transactions,* which bears the date September 18th, 1671. His first words, which have been "English't out of the French," run as follows, and also point to the great rarity of sun-spots at that period:—

"It is now about twenty years since that Astronomers have not seen any considerable Spots in the Sun, though before that time, since the Invention of Telescopes, they have from time to time observed them. The Sun appeared all that while with an entire brightness, and Signor Cassini saw him so the ninth of this month of August.

"But the Eleventh of the same, about six o'clock at night, being furnisht only with a three foot glass, he remarked in the Sun's disque Two Spots very dark, distant from his apparent Center about the third part of his Semi-diameter."

Then follows a description of the appearances of the spots and of their positions on the three days of observation, August 11th, 12th and 13th, but this, though so interesting to the astronomers of the time, need not claim our attention. The point of wonder to them was that any spots at all should be seen; the point of wonder to us is that they were not common and familiar objects.

This group was observed at its return in the next rotation, amongst others by Dr. Hooke, the celebrated Professor of Geometry at Gresham College. But after it passed off the disc the second time the sun appears to have remained spot-free until November in the following year, when Le Monnier records the passage of a group. Then again a blank interval follows until in July and August, 1676, a fresh outburst occurred which drew the attention of several astronomers, our own Flamsteed and Halley in England, as well as Cassini at Paris. Later in the same year Cassini records another group which was seen during four rotations, and of this he says: "This is the third spot which has appeared in the year 1676, in which they have been more frequent than they have been during the twenty years preceding." A group is recorded in April, 1677, two or three in 1678. In connection with one of these appearing towards the end of May, Cassini remarks that the spot "was quite close to the limb in the middle of a region brighter than the rest of the surface of the sun, and was followed by a great number of other little markings of a like character... These have been called Faculae by Scheiner, who has often observed them. They have already appeared once this year, after the dissipation of the spots which appeared from the 25th of February, to the 4th of March."

In 1680, spots were seen in May, June, and August, the group of May being a large one. In 1681, Siverus and Vagetius record spots in May and June. Then we come to 1684, when Flamsteed again has given us an observation of a spot on the sun's disc. "These appearances", he adds, "however frequent in the

days of Scheiner and Galileo, have been so rare of late that this is the only one I have seen in his face since December, 1676."

This year, 1684, seems to have shown several spot-groups; 1686, two or three; 1687, none; for Cassini states in 1688 that "no matter what care he had taken to observe the sun when the sky was clear, he had not been able, since the year 1686, to detect any spot upon it until the 12th of May last." A few spots were seen in 1688 and 1689; then nearly six years passed without any being observed, for the next record is one of a great spot in May, 1695. Again a barren period set in, and it is not until the eighteenth century was about to dawn that we find any further observations. De la Hire and Cassini observed a great spot in November, 1700; the spot of May, 1695, was thus the only one recorded in a period of eleven years.

This long-continued dearth was now approaching the close. The Rev. William Derham, who made a special study of the sun at Upminster, has given a record of his observations in No. 330 of the *Philosophical Transactions*, and in most months of 1704 and 1705 one or more spots were seen. More remarkable still, in January, 1704, and again in October, 1705, the appearance of two separate groups on the sun at the same time was signalized. "Since the observations of Scheiner", is the comment of the *Histoire de l'Academie*, "made sixty years ago, one has scarcely ever seen two groups of spots on the sun at the same time". The wonder was, however, destined to become more common, for in 1707 it happened twice.

A new decline then set in. Derham's observation of a spot in January, 1710, and De la Hire's of another in October of the same year, appear to be the last for a considerable time, the sun being spot-free, according to Wurzelbauer, from the time of the disappearance of the last-mentioned group, October 29th, 1710, till May 19th, 1713. But a few years later quite a different state of things prevailed, and in 1716 the *Histoire* records: "This year has had still more spots than the preceding, and perhaps no other year has had so many. There have been twenty-one different appearances of them counting only as a single appearance that of several different spots at a time. Only the months of February, March, October, and December have been free from them. In the other months the appearances closely followed each other, and to compensate several lasted only a short time. The phenomenon of two different spots at the same time has entirely ceased to be rare. It has been seen on April 20th and 21st, May 11th, July 26th, but that which is yet more remarkable, from August 30th to September 3rd eight different and totally distinct groups of spots have been seen in different regions of the sun. No diminution in the brightness of the sun has, however, been perceived."

With this great increase in activity, which rose to a yet more decided maximum in 1718, the long period of depression came to an end. It is not so certain when it commenced. A maximum was due, according to the ordinary course of the eleven years period, in 1649, but there are very few observations of spots at the time, and not a few notices in the years from 1648 to 1660 that the sun was spot-free.

Perhaps the most striking evidence we have of the reality of this prolonged dearth lies in the evident excitement and interest which the occasional appearance

of a spot called forth. Picard, who independently discovered Cassini's spot of 1671, when at sea near the Texel, declares that he "was so much the better pleased at discovering it, since it was ten whole years since he had seen one, no matter how great the care which he had taken from time to time to watch for them". Cassini, again and again, and Flamsteed also, announce the time when a spot may be expected to return, for the benefit of their brother astronomers, since it is a "phenomenon which it is not in our power to see whenever we wish." And the references to the more prolific times of Scheiner and Galileo are not infrequent.

On the whole, then, it appears probable that after the maximum of 1639-40 had fairly died out—that is, after about 1643—a prolonged period of almost entire absence of spots set in, a period broken only by the very rare apparition of a single spot now and then, and by the feeble revival of 1703-7, and which cannot be considered to have terminated until the setting in of the maximum of 1715-20. For all this period, or at any rate from 1655 to 1703, the ordinary progress of the solar cycle appears to have been in abeyance, and we can hardly speak of it but as an extraordinary and immensely prolonged minimum.

And yet, just as in a deeply inundated country the loftiest objects will still raise their heads above the flood, and a spire here, a hill, a tower, a tree there, enable one to trace out the configuration of the submerged champaign, so the few solitary spots observed seem to mark out the crests of a sunken spot-curve. 1660, 1671, 1684, 1695, 1705, the years most notable for such stray spots as were observed correspond as nearly as we can expect to the theoretical dates of maximum.

It may be objected, perhaps, that bearing in mind the feeble instruments of those days, and the paucity of observers, it may well have happened that many spots may have passed unnoticed during the seventy years in question. But no great instrumental power is needed to detect the presence of a sun-spot, and indeed a single diligent observer using his unassisted sight during the last twenty-five years would have compiled a far heavier record than all the astronomers of Europe have been able to hand down to us for the years between 1643 and 1715. Besides, telescopes were certainly considerably more powerful than those in use earlier in the century. Yet we have but to refer to the works of Galileo, or to the plates, drawn with such evident care and fidelity, which adorn Scheiner's huge "Rosa Ursina", to be assured that outbursts such as the sun presented in 1625-27 could never have passed unnoticed fifty years later.

Nor were the observers few. In England there were Flamsteed, Halley, Hooke, Gray, Derham; in Holland, Huyghens; in Germany, Vogelius, Siverus, Vagetius, Wurzelbauer; in France, Picard, De la Hire, Maraldi, and above all Cassini. Indeed Derham, writing in 1711, well anticipates this objection. "There are", he says, "doubtless great intervals sometimes when the sun is free, as between the years 1660 and 1671, 1676 and 1684. In which time Spots could hardly escape the sight of so many curious Observers of the Sun, as were then perpetually peeping upon him with their Telescopes in England, France, Germany, Italy, and all the World over; whatever might be before, from Scheiner's time." And the fact that a new spot was apt to be independently discovered by more than one observer shows that the watch was carefully kept. The sentinels were neither

few nor inefficient, nor can many stranger spots have eluded their vigilance, except under the cover of continued cloud.

A few, perhaps, did pass unnoticed. The watchful Cassini thus missed the spot of January 22nd, 1710, which Derham detected. Flamsteed let slip several which Cassini observed, but after making the utmost allowance for imperfection in the record there can be no doubt that the seventy years in question were barren of spots to a degree to which there has been nothing to correspond since.

The unanimity with which, when the earlier days of revival had come, all observers speak of the great frequency of spots as quite a new experience, is irrefragable evidence that the change was a very real one... Derham, in 1711, refers to 1690-99 as a time "when Spots on the Sun were more rare than for these three or four years past they have been," and yet his record for these more prolific years, when compared with those of the present century, shows that 1704 and 1705, though so abnormally active as compared with the sixty years that had preceded them, were little (if any) richer than the years of an ordinary minimum. We expect now about sixty per cent. of the days of such a year to be free from spots; for the years immediately preceding or following minimum say about twenty-five per cent. Near maximum we expect to get five or six years running without a single instance of the sun being spot-free. And so far from two groups at once on the sun being a rarity, we look to have a dozen on the average, a number which may rise to seventeen or eighteen on occasion, as it did in December last; whilst a maximum year, like those of 1892 or 1893, will show three or four hundred distinct spot-groups, instead of the twenty-one which were considered so extraordinary a record in 1716. It would be quite impossible in these days for a Wurzelbauer, however small his instrument, to observe "daily" for five years without seeing a spot, or for a Cassini or Picard to do the same "from time to time" over a period of ten years, with a like barren result.

This long-continued solar rest suggests many questions to which we can find no reply. How we regret the absence of magnetic records, and how valuable would be a few of those ponderous volumes of rainfall and temperature that, when published by modern observatories and in these days, we are apt to look upon with scorn...

But there were a few total eclipses—those of 1654, 1659, and 1661—and, they give us no hint of either red flames or of corona, whereas we get observations of both from the eclipse of 1715, and of the red flames from that of 1706. We cannot, therefore, say what shape the corona, which now appears to vary in such sympathy with the spot-curve, had during the period. Is it possible that, like the spots, it was in a state of partial abeyance?

In our next issue we will consider the auroral observations of the 17th century as an indication of how the earth's magnetic activity was affected by this lack of sun-spots.

REVIEW OF PUBLICATIONS

What Industry Owes to Chemical Science, based on a scheme by Richard B. Pilcher and Frank Butler-Jones, with Fifty Contributors. Pages viii, 372; 5 × 8½ in. Brooklyn, N.Y., Chemical Publishing Co. Inc.; Toronto: General Publishing; 1946. Price in Canada, $7.00.

This book grew out of twenty articles contributed to *The Engineer* (England) in 1916-17. They were written under the stress of war-time conditions and there was no intention to make them into a book. However that was done and the first edition was published in 1918. It had a ready sale and a second edition printed next year was soon sold out. Many inquiries continued to be received for the book and so an entirely new edition was prepared under the auspices of the Royal Institute of Chemistry. The present work is the first American edition of it.

There are fifty-two separate articles, on such subjects as fertilizers, nutrition, sugar, cosmetics, laundry, textiles, plastics, photography, glass, road transport, etc. Distributed among them are thirteen pages of portraits of masters of chemical research, from Robert Boyle to the present.

On reading various articles chosen at random one realizes that the writer in each case is a master of his subject. Further, they are in simple, clear language which the general reader as well as the technical person can understand. Another valuable feature is the full index which allows quick reference to any subject mentioned in the book.

C. A. C.

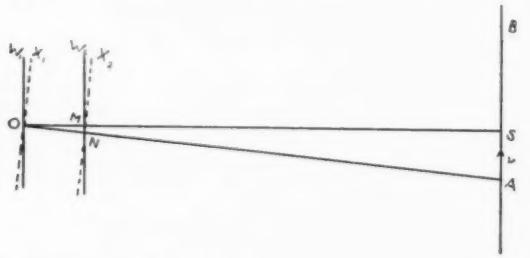
NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Aberration of Light and the Red Shift

A Journal correspondent has brought up a point which may have occurred to others as well, and which is worth answering, although we conclude that his reasoning is faulty.

The point concerns aberration of light and a supposed consequence relating to the red shift of the nebulae. The correspondent considers a source of light such as S in the diagram which is moving with velocity v across the line of sight (towards B, the observer being



at O). He reasons that, due to aberration, the light appears to come from a direction A, such that the angle SOA is $\tan^{-1}\frac{v}{c} = a$. Then, he claims, the direction from which the light is received is not perpendicular to the successive wave-fronts W_1 and W_2; therefore the distance between wave-fronts is no longer the original wave-length, λ, but rather $\lambda \sec a$. This would yield a change in wave-length, or red shift, of λ (sec a -1) or $\lambda\left(\sqrt{1+\frac{v^2}{c^2}}-1\right)$.

This supposed red shift due to translational velocity would ordinarily be small, the correspondent points out, but could account for red shifts of $1/7$ λ if the translational velocity were as much as $\tan^{-1}\frac{v}{c}$ and that the wave-fronts arriving at O are perpendicular to one-half the velocity of light. He asks if the red shifts of the nebulae

might thus be interpreted as due to a rotation of the metagalaxy about our own galaxy as centre.

The answer is that if we examine the problem more carefully we find there is no such red shift due to translational velocity of the source. The correspondent has forgotten that when the light started out for the observer, the source was back at A such that SOA is $\tan^{-1}\frac{v}{c}$ and that the wave-fronts arriving at O are perpendicular to AO, such as X_1 and X_2. The distance between them along the line of reception of the light is therefore the original wave-length, λ. There is no change of wave-length.

Actually this illustrates very well the fact that for a steady velocity of either observer or source across the line of sight the "aberration" resolves itself into the object appearing to be in the direction that it was when the light started out.

J. F. HEARD.

A TELESCOPE STOLEN—WHAT NEXT?

It is with regret that we have learned that on Saturday evening, October 26, a telescope belonging to Mr. J. V. Argyle, 360 Holland Avenue, Ottawa, was stolen from his backyard where it was mounted. A description of the instrument follows, which, it is hoped, may assist in its recovery:

The tube is sheet steel finished in grey-green lacquer. The eye-piece is a Pierce one-inch adjustable eye-piece. The diagonal is a Pierce aluminum-coated diagonal. The mirror itself is home-made 6 inches in diameter, ground and polished on the wrong side, that is to say, the chamfer is on the back side of the mirror rather than the front. The mirror was aluminized in Chicago this summer. There are several small chips around the edge and the mirror cell is mounted on the tube by means of four threaded studs, concentric springs, and adjusted with wing nuts. The tube is approximately 56 inches in length, and 8 inches in diameter.

C. A. C.

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